The Transportation Energy Future Is Uncertain: But It Is BIG

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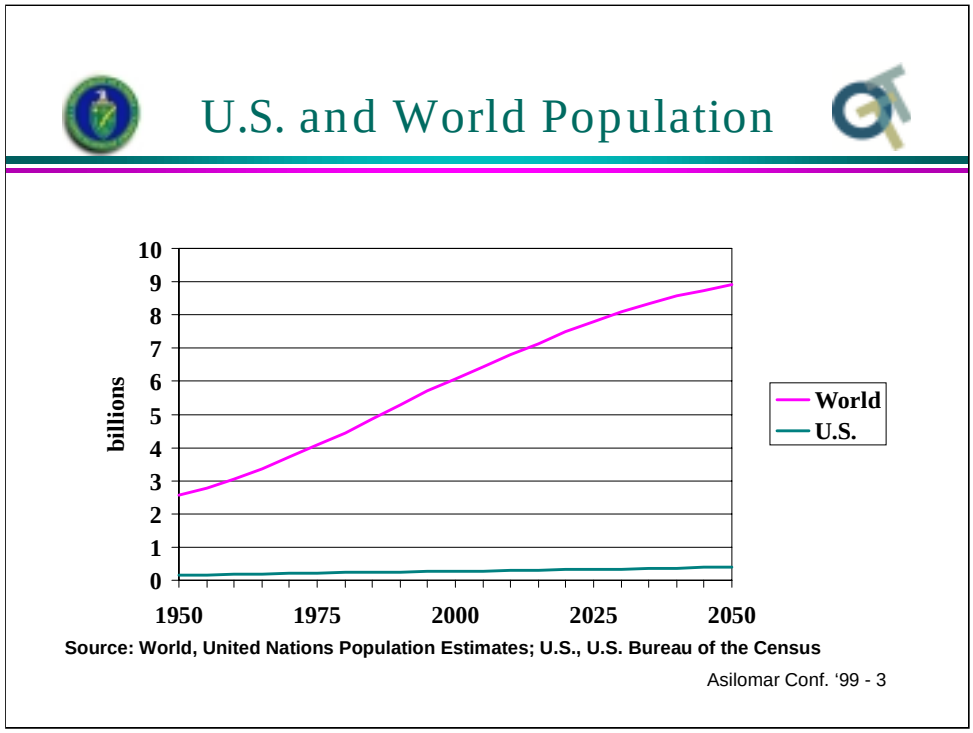
I had the help of my Analytic Team (John Maples, Jim Moore, and Alicia Birky) in preparing this presentation.

The OTT website is listed here. Check it out to find out what we are doing. Try the "analysis" page and see our "Fact of the Week".

Outline

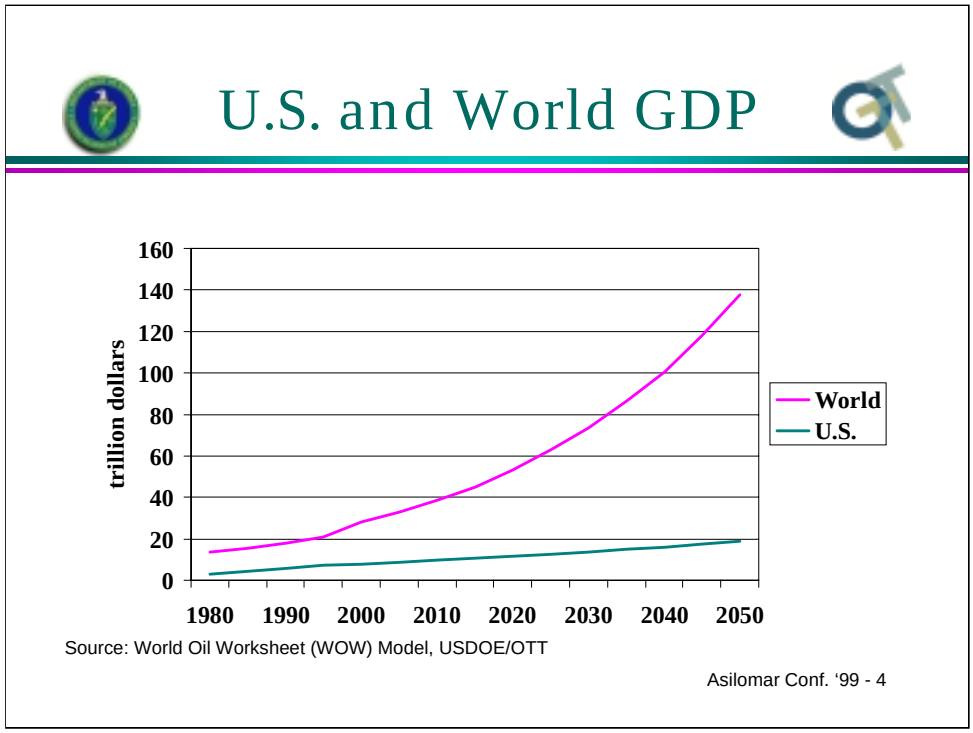
- The Forcing Factors Are Big
- The Demands Are Big
- The Fossil Fuel Supplies Are Big
- What the public thinks is important
- The Oil Use Problem
- The GHG Problem
- The Policies Have to be Big
- Conclusions

Here is the outline of my presentation.



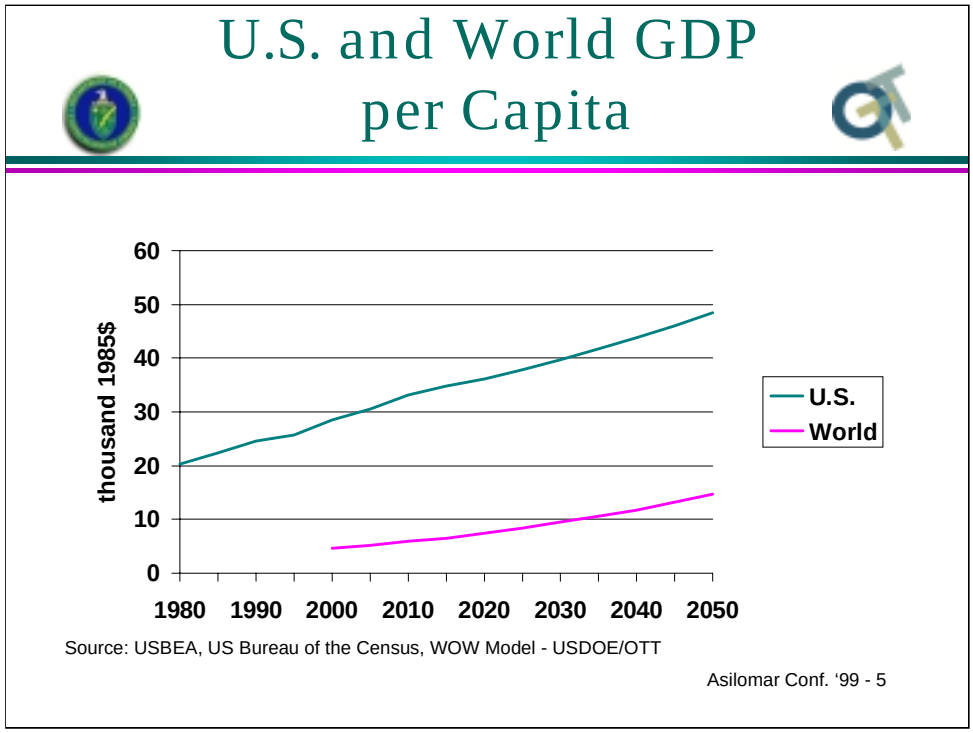
The US share of world population is very small today (around 5%) and it is expected to get even smaller according to these forecasts.

The world population growth is expected to reach nine billion people by the year 2050. The rate of growth is projected to slow down over time.



These curves represent a growth rate in world GDP of 3.2% and in US GDP of 2.8%.

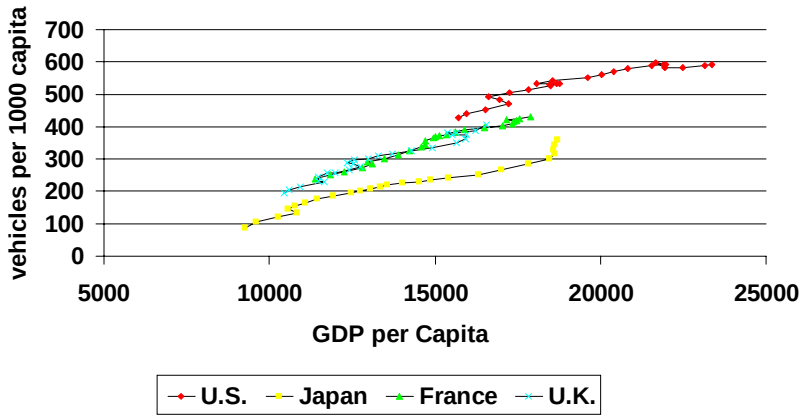
The actual GDP growth rate will be the single most important factor in determining the amount of personal and freight transportation demand in the future.



These curves result from dividing the forecasted GDP by the forecasted population on the previous two slides.

The world GDP/capita in the year 2050 equals the GPD/capita that existed in the US in 1965. Think about what that means if 9 billion people demand and use transportation like the US did 34 years ago.

Vehicle Ownership as a Function of GDP / Capita



Lee Schipper et al , "People on the Move and Goods on the Go" LBNL

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These curves, supplied by Lee Schipper, show the demand for vehicle ownership as a function of GDP/capita.

In the spreadsheet model that we have built to project to 2050, we assume that all countries will follow one of these three general curves.

This spreadsheet model is called the WOW Model (World Oil Worksheet Model).

World Vehicle Population Projections for 2050

Case	Assumptions			Number of Vehicles (billions)
	Passenger Veh./Capita	Population Growth Rate	GDP Growth Rate	
1	Like U.S.	0.88%	3.5%	4.5
2	U.S./Euro/ Japan	0.88%	3.5%	3.4
3	Like U.S.	0.88%	3.0%	3.3
4	U.S./Euro/ Euro	1.32%	3.5%	3.8
5	U.S./Euro/ Euro	0.88%	3.2%	3.0

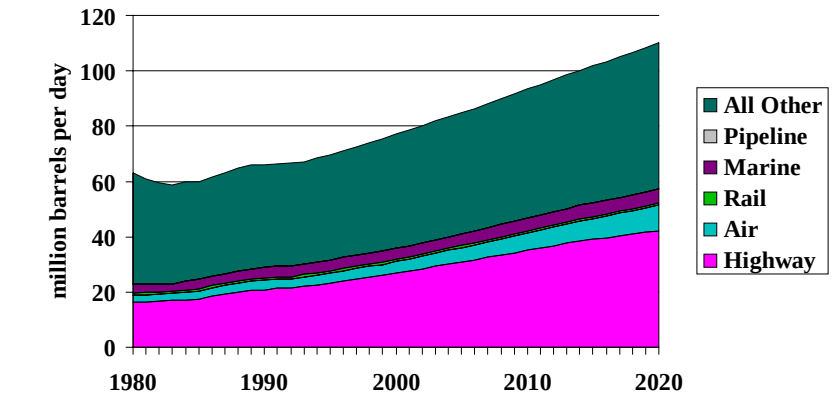
Source: World Oil Worksheet (WOW) Model - USDOE/OTT

This table shows that the total number of projected vehicles for 2050 is very dependent on the assumptions about which curve on the previous slide is followed, the population growth rate, and the GDP growth rate.

The largest number of vehicles shown here is for Case 1. This assumes all the countries follow the US curve with respect to vehicles/capita as a function of GDP/capita, population grows at .88% per year, and GDP grows at 3.5% pre year. With 4.5 billion vehicles in 2050, this is similar to the vehicle ownership rate in the US in 1970.

The smallest number of vehicles, 3.0 billion, results when most of the world follows the European curve and GDP grows at a slower rate of 3.2%. This would be equal to the vehicle ownership rate in the US in 1955.

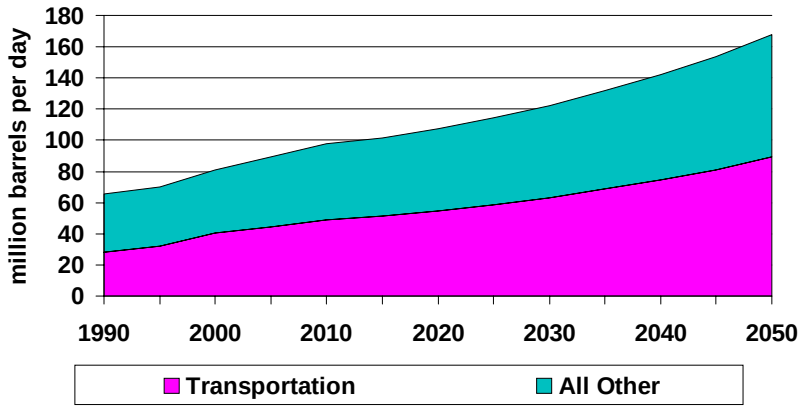
EIA Projected World Oil Use



Source: EIA IEO'99

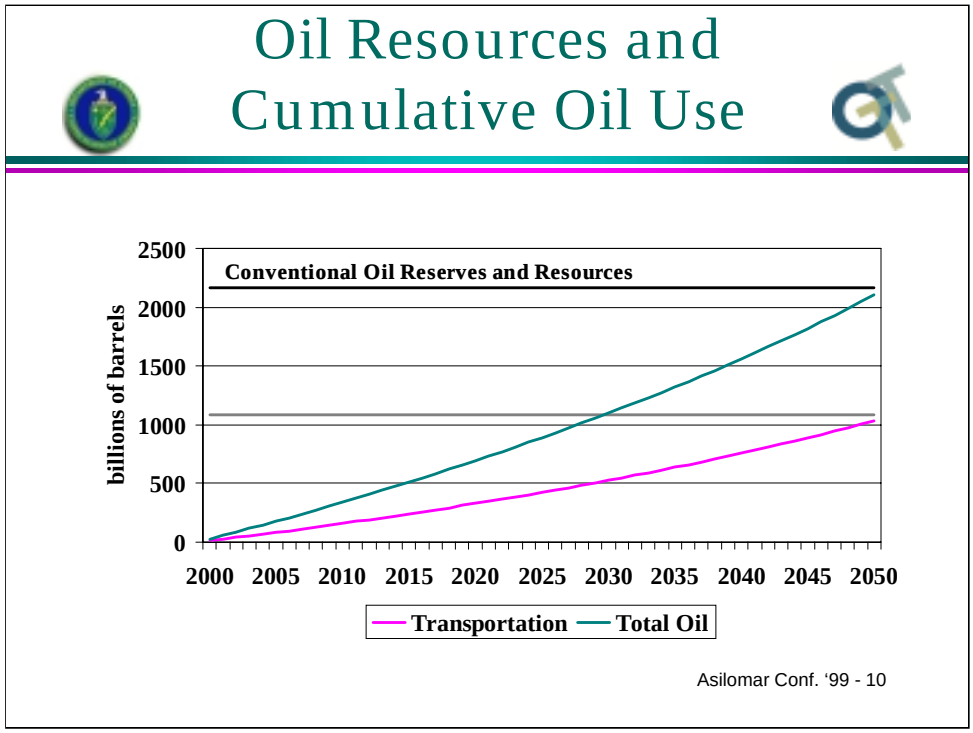
This is the projected world oil use that EIA made in their most recent International Energy Outlook.

World Oil Use



Source: World Oil Worksheet (WOW) Model, USDOE/OTT

Here is world oil use projected to 2050 using WOW and the EIA projection out to 2020.

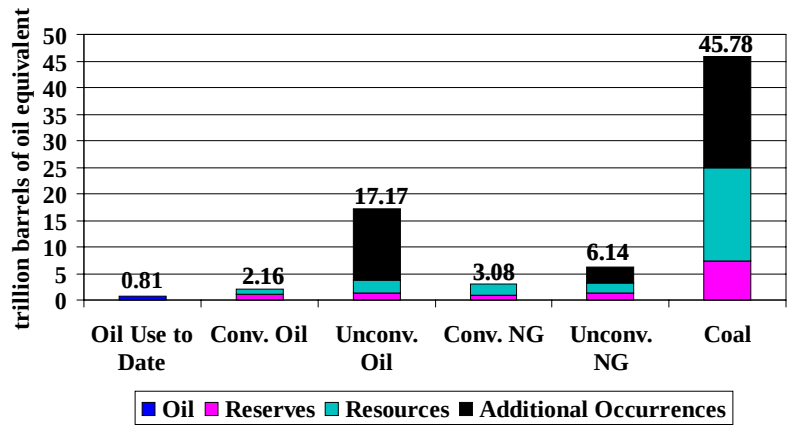


The top horizontal line shows the remaining conventional oil resources as estimated by IIASA (International Institute for Applied Systems Analysis). The lighter horizontal line at a little over 1000 million barrels is one-half the IIASA resource level. The theory is that when half of a resource is consumed, the price will rise and continue to increase if demand remains strong.

The red (bottom) line shows the cumulative world transportation oil use. The blue (top) line shows the cumulative total world oil use.

The curve crosses the one-half line around 2028. Thus, this is the year that would experience an upward movement in oil prices, given this resource estimate (which is high relative to the range of estimates in the literature).

The Fossil Fuel Potential Is Big



Source: H.H. Rogner, "An Assessment of World Hydrocarbon Resources," Annual Review of Energy and Environment, 1997, p. 249.

The amount of remaining fossil fuel is tremendous. The small bar on the left represents all the oil that has been consumed in recorded history.

The amount of conventional oil remaining is larger than that according to Rogner. He has placed all the fossil fuel resource estimates on an equal basis, so we show his numbers (same as for IIASA for oil).

Unconventional oil resources (including tar sands and shale) are nearly eight times those of conventional oil.

Conventional natural gas resources are somewhat larger than those for conventional oil, but unconventional natural gas resources are quite a bit less than those for unconventional oil. Hydrates (which are a potential source for natural gas) are so large that their value would be three times larger than the highest y-axis value shown here.

As can be seen, the barrels of oil equivalent of coal is vast.

The message here is that the world is not going to run out of fossil fuels for a long time!

Estimates of Remaining Oil Resources

Source	Billion Barrels	Year ½ is Consumed
Campbell & Laherrere (Scientific America)	1000	2015
Hatfield (Univ. of Toledo)	1550	2023
USGS (OTT Fuels Database)	1684	2024
Edwards (Univ. of Colorado)	2036	2029
IIASA	2163	2030
Energy Modeling Forum 14	2330	2032

This table shows six estimates of remaining conventional oil resources.

The year at which half would be consumed ranges from 2015 to 2032.

Future Transportation Problems

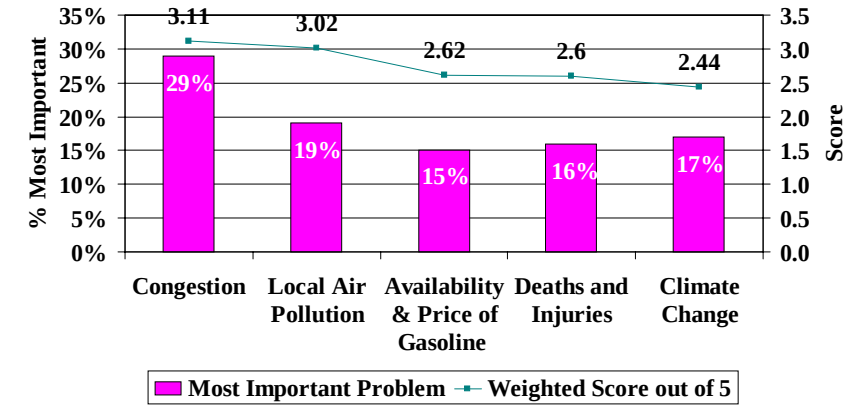
"Thinking about the future, please rank the following transportation problems in the order of importance to the U.S. in the year 2020."

- Traffic Congestion
- Deaths and serious injuries in vehicle accidents
- Availability and/or price of gasoline
- Local air pollution from vehicles
- Global warming or climate change caused by vehicles

Source: Opinion Research Corp. for NREL, 1008 responses to phone survey conducted 8/99

These questions were rotated from respondent to respondent, so that the sequence would not add a bias.

Most Important Transportation Problem



Source: Opinion Research Corp. for NREL, 1008 responses to phone survey conducted 8/99

Unsurprisingly, congestion was picked most often as the biggest transportation problem in 20 years. But all the options received some support for being a major problem in the future.

If the option responses are weighted 5 for most important, 4 for next most important, etc., the scores shown by the line results. Air pollution is very close to congestion, and the other three options are close to one another.

Demographics of Responses

- Availability/Price of Gasoline - 15%
  - Males - 17%
  - 65+ years old - 12%
  - South - 11%
  - West - 19%
  - Non-metro - 21%
- Global Warming or Climate Change - 17%
  - 25-34 years old - 21%
  - 65+ years old - 10%
  - North Central - 13%
  - South - 21%

This shows the demographics of some of the respondents which are most different from the average.

Congestion

- Solutions
  - » More Roads (more energy)
  - » Stretch out peak periods
  - » Land use changes
    - – Concentration
    - – Further Deconcentration
  - » ITS

Many of the potential solutions to congestion will generate more transportation energy use: more roads, further deconcentration, and more highway capacity resulting from ITS improvements.

Safety and Air Pollution

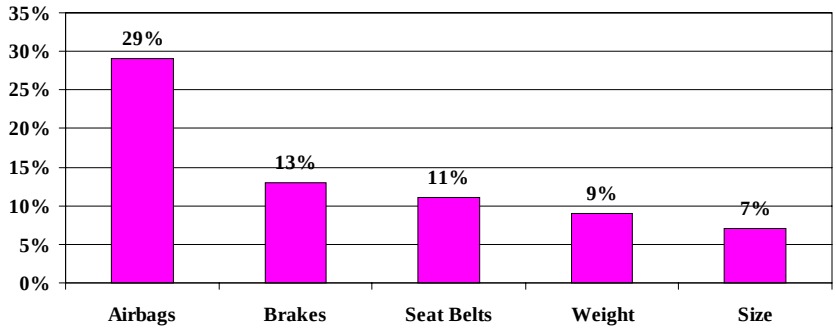
- Reduce Deaths and Injuries
  - » Buy larger vehicles
  - » Better vehicle design
- Reduce Local Air Pollution
  - » Incentive to do this is strong
  - » Vehicles and fuels are getting cleaner

One of the solutions to vehicle safety is to buy a larger and heavier vehicle, which many people seem to be doing today.

I feel that air pollution is a problem that will, and is, bringing forth its own solution.

Vehicle Safety

"In purchasing your next new vehicle, what vehicle attribute will you value most in terms of Safety?"



Source: Opinion Research Corp for NREL, 1007 responses to phone survey conducted 1/97

Here is what respondents said they are looking for to improve safety. You can see that 16% mentioned size/weight as most important.

That Leaves Oil Use and GHG Emissions

Growth From 2000 to 2020

	Oil (mbpd)	Carbon from Oil Use (MMTCe)
U.S.	19.9 → 24.7 (24.1%)	647 → 818 (26.4%)
World	77.1 → 110.1 (42.8%)	2686 → 3823 (42.3%)

Source: EIA 1999

These are the EIA projections. US growth is less than that expected for the world.

Security Costs of Oil

- Strategic Petroleum Reserve Program:
  - » Cumulative funding 1976-1998 totaled $38 billion (1998$). (SPR 1998 Annual Report)
  - » $160.1 million appropriated for FY1999.
- Military expenditures for defending oil supplies from the Middle East estimated at $32 billion per year (1996$). (Average of 6 studies; Transportation Energy Databook-19)

These are the security cost of oil. The estimated $32 billion per year for military expenses to defend Mideast oil amounts to about 12 cents per gallon of gasoline.

OPEC a Bust?

- According to EIA, OPEC actions have increased world oil prices by 50% over the last 8 months
- OPEC pledged reductions of 1.7 mbpd
- Non-OPEC countries (Mexico, Norway, Russia, and Oman) pledged to cut an additional 0.4 mbpd
- This 2.1 mbpd is only 3% of world production

Source: EIA - OPEC Fact Sheet

Many people had said that OPEC had lost its power. But recent events show this to be wrong.

OPEC even has four non-OPEC countries joining them to reduce oil production and raise its price.

The Cumulative U.S. Cost of Oil (1970-1998) (Trillions of Dollars)

	Present Value Dollars
Wealth Transfer	$2.3
Potential GDP Loss	$2.0
Macroeconomic Adjustment	$1.6
Total	$5.9

Source: David Greene, e-mail of June 2, 1999

These estimates by David Greene place the cartel cost of oil to the US at $5.9 trillion over the past 28 years (in present value terms). This compares with the current US GDP of about $8 trillion.

Why Would OPEC Act as EIA Assumes?

	Reference Case 2020	High Price Case 2020
OPEC Production	53.5 mbpd	46.7 mbpd
World Oil Prices	$22.73/bbl	$29.35/bbl
OPEC Revenues	$444 billion	$500 billion

Source: International Energy Outlook, 1999, EIA, March 1999.

It would appear that OPEC would benefit a lot more by producing at the High Price Case presented by EIA, rather than producing at the Reference Case level. Both cases require OPEC to increase its production capacity substantially over its 1997 level: 57% and 80%, respectively.

OPEC earns higher revenue, keeps more of its oil in the ground, and has lower costs for production in the High Price Case. Why would it not follow this path?

The cost of alternatives to conventional oil might be the only reason for oil prices not reaching the higher price in 2020.

Recoverable Reserves

Country	Crude Oil	Natural Gas	Coal
US	2.2%	3.3%	25.3%
Russia	4.8%	33.4%	15.9%
"Big Mid-East"	64.8%	26.9%	0.0%
China	2.4%	0.8%	11.6%
India	0.4%	0.3%	7.6%
Total (percent)	74.5%	64.7%	60.4%
Total (bboe)	760.4	583.3	2411.1
World Total (bboe)	1020.1	900.9	3993.3

bboe: billion barrels oil equivalent
Big Mid-East: Iran, Iraq, Kuwait, Saudi Arabia, UAE

Source: EIA

The most likely alternative to compete with conventional oil with respect to price will be liquids from cheap natural gas.

But the cheap natural gas is mostly found in the Mideast and in Russia. This does not sound like it will be a fuel with greater security. Also, almost all liquids from natural gas will be imported, whereas oil is only 50% imported at this time.

Global Climate Change

- Changes since pre-industrial age:
  - » CO_2 concentrations have risen from 280 ppmv to 360 ppmv.
  - » Global mean temperature is 0.3 - 0.6°C higher (0.5 - 1.0 °F).
  - » Sea level has risen 10 - 25 cm (4 - 9.9 inches).
- Global mean temperature difference between ice age low and warm period high is 5 - 6°C.

Here are the changes that have taken place with respect to CO2 concentration, global mean temperature, and sea level.

Climate Change: IPCC-95 Mid-Range Emissions Scenario

- Scenario IS92a ("business-as-usual"):
  - » Total annual world CO_2 emissions rise from 7.4 GtC in 1990 to 20.3 GtC in 2100.
  - » Atmospheric concentrations reach 650-750 ppmv by 2100 but continue to rise.
- Conditions by 2100 w.r.t 1961-1990:

Climate Sensitivity	Global Mean ΔT °C	°F	Sea Level Rise cm	inches
Low	1.5	2.7	20	7.9
Mid	2.0	3.6	50	19.7
High	3.0	5.4	90	35.4

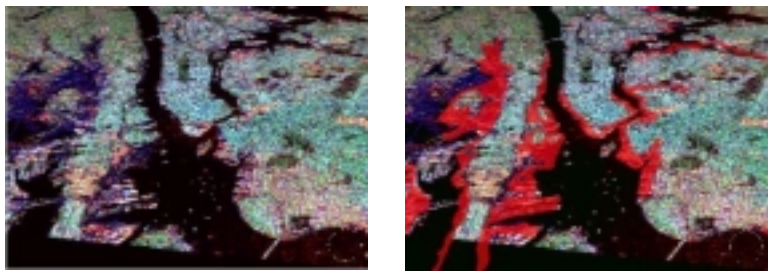
Source: IPCC, 1995

The IPCC has estimated future CO2 emissions and concentrations.

Their effect on future temperature and sea level is uncertain, but with high sensitivity, 2100 temperatures could be 5.4 F higher than today and the sea level could rise about one meter.

Sea Level Rise due to Climate Change

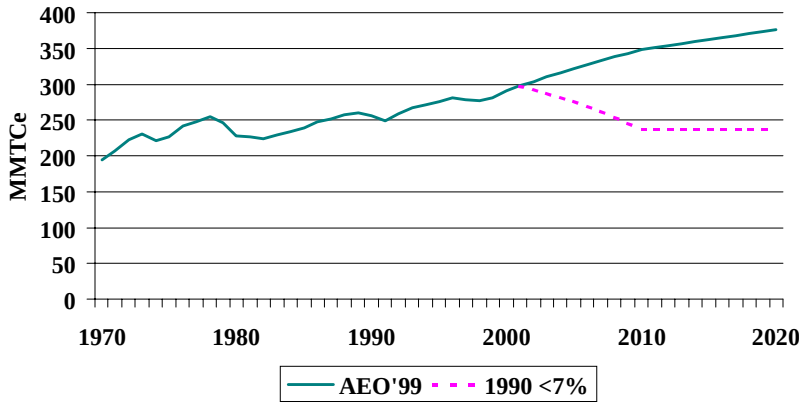
Before **After**



New York City looking toward Manhattan. Areas in red would be affected by 1 meter of sea level rise with accompanying high tide and storm surge. Image created by Dr. Vivian Gornitz at Columbia University based on Space Shuttle imagery overlaid on Digital Elevation Model (DEM) data from the USGS.
http://www.prescott.edu/nasa/newyork.htm

This is a look at what might happen to Manhattan with a one meter rise in sea level.

Light Vehicle Carbon Emissions Projections and Goals



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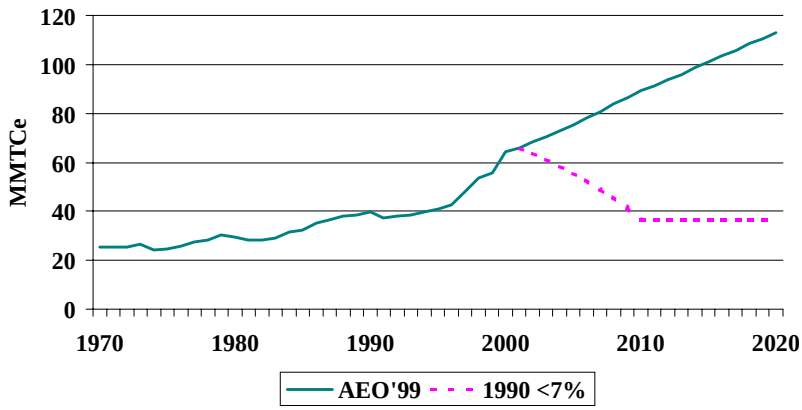
This is what would have to happen to carbon emissions from light vehicles, if this activity had to reduce it emissions to the Kyoto target for the US.

Air Travel Carbon Emissions Projections and Goals



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The air travel emissions would have to be reduced by about two-thirds.

Potential Demand Reduction Strategies

- Population Concentration
- Mass Transit
- Tele-everything

These are three potential ways to reduce the demand for travel.

Reduce VMT via Population Concentration?

A May 1999 Survey showed that:

- 83% of 5,000 respondents would purchase “a $150,000 larger, detached single family house in an outlying suburban area, with longer distances to work, public transportation, and shopping”
- Rather than “a $150,000 townhouse in an urban setting close to public transportation, work, and shopping.”

The public appears to want to live in less concentrated areas rather than becoming more concentrated.

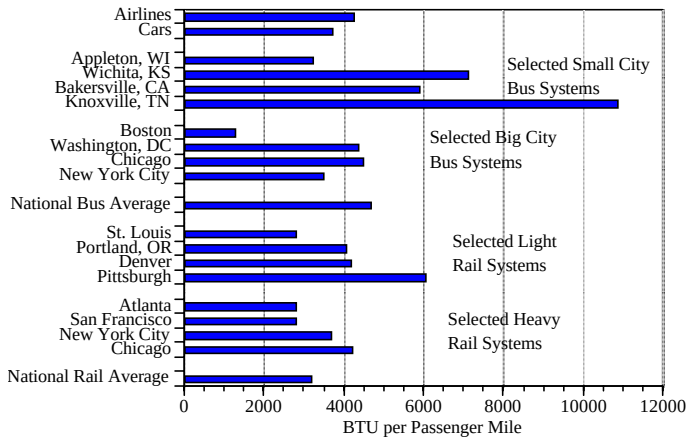
People's Perception of the Impact of Select Aspects of Society Over the Last Century

Societal Aspect	Better	Worse
The Automobile	91%	6%
Airline Travel	77%	8%
Growth of the Suburbs	52%	21%
The Interstate Highway System	84%	8%

Source: PEW Research - 4/6-5/6/99 phone survey of 1546 adults

Another survey shows that the public thinks that the automobile, airline travel, the growth of suburbs, and the interstate highway system have been beneficial.

BTU per Passenger Mile for U.S. Transit in 1995



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The idea that shifting to mass transit will save energy is no longer true in most cases, on the average. Over the last 25 years, autos and aircraft have become more efficient and mass transit has, in most cases, become less efficient.

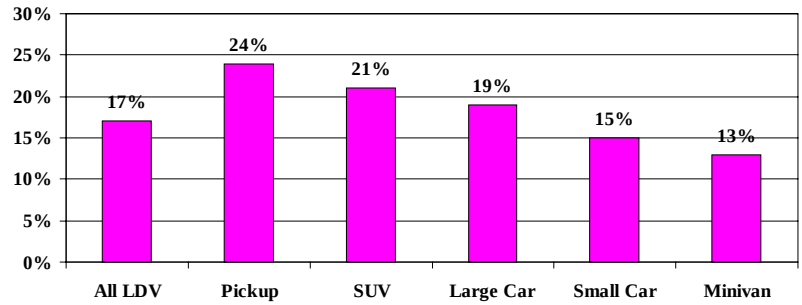
Tele-Everything: Potential VMT Reduction from Trip Purpose Perspective

Purpose	Share of VMT	Reduction Measure	Purpose Reduction	Overall Reduction
Work	34.7%	10% telecommute 2 out of 5 days	4%	1.4%
Shopping	11.9%	5% teleshop	5%	0.6%
Vacation/Visit	14.4%	Reduce by 10%	10%	1.4%
Family Related	24.8%	Reduce by 5%	5%	1.2%
Other Social/ Rec.	14.2%	Reduce by 10%	10%	1.4%
Total				6%

This is a ballpark guess at the potential to reduce VMT from some optimistic estimates of electronic substitution for different trip purposes.

Diesel Preference

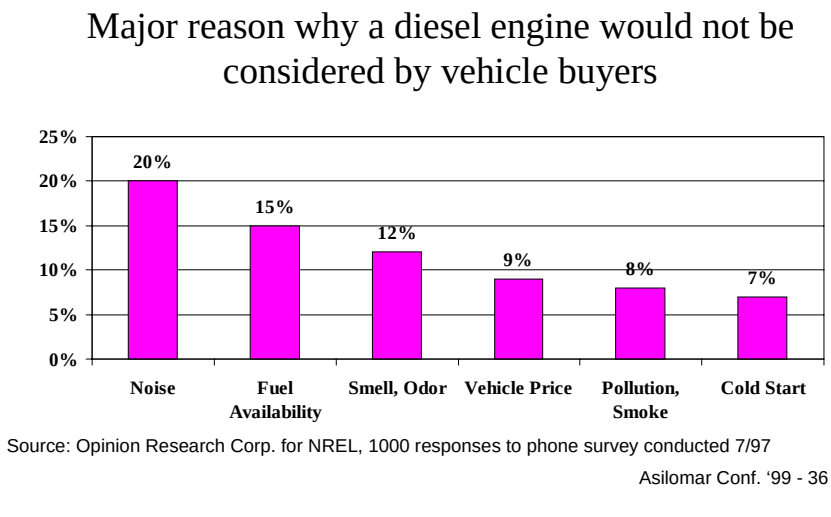
Percent of vehicle buyers willing to pay more than $1,000 for a diesel engine that improves mpg by 50% and is equally clean, powerful, odorless, and smooth running as the gasoline engine.



Source: Opinion Research Corp. for NREL, 981 responses to a phone survey conducted 2/98

This survey shows that the interest in purchasing a diesel engine is about 17% and the interest varies by vehicle type.

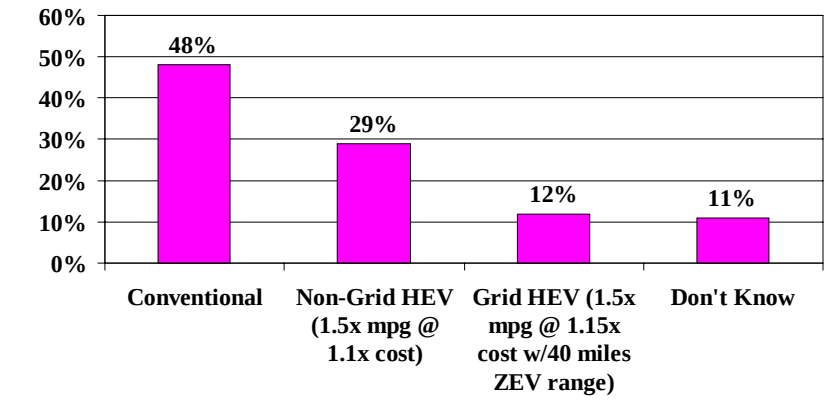
Diesel Engines



Source: Opinion Research Corp. for NREL, 1000 responses to phone survey conducted 7/97

The major reason why a diesel engine would not be considered is shown here. Some of these problems with diesel engines have been solved with the latest technology.

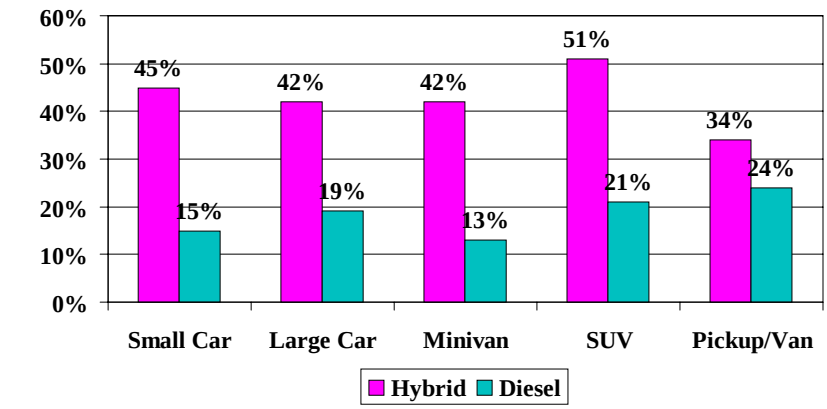
Next New Vehicle Purchase



Source: Opinion Research Corp. for NREL, 1008 responses to phone survey conducted 8/99

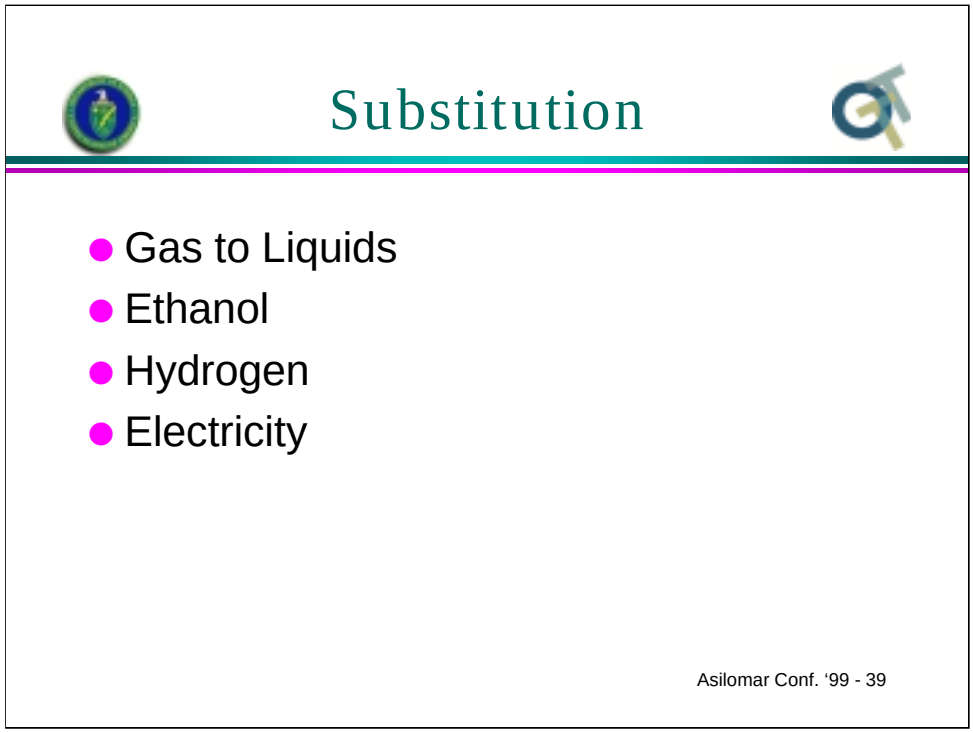
This survey on hybrid vehicle interest shows that more respondents liked the cheaper hybrid that was not able to charge from the grid.

Consumer Preference by Vehicle Type



Source: Opinion Research Corp. for NREL, separate questions asked on 2/98 and 8/99

When the interest in the two types of hybrids is combined and compared to the interest in the diesel, this comparison by vehicle type results. For each type, the hybrid has a greater interest than the diesel.



Substitution is another way to reduce oil use and carbon emissions.

The most likely gas to liquid is FT-diesel. But this will be almost 100% imported and high in carbon.

Ethanol is a very low-carbon fuel, but its ability to substitute for a large fraction of transportation oil use will be limited by the land requirements to grow the biomass crops.

Hydrogen requires a cheap and renewable means of electricity to become viable.

The best prospect for affordable and renewable electricity in the US will probably be from windmills, which require land and are not always popular with nearby residents.

Policy Options to Reduce Oil Use and Carbon

Option	Oil Reduction Effectiveness	Political Feasibility	Gov't Cost	Public Acceptance
CAFÉ	H	L	L	H
Feebates	H	M	L	H
Light Truck Guzzler	H	M	L	H
Pay at the Pump	M	L	M	L
Oil Tax	M	L	L	L
Carbon Tax	M	M	L	L
R&D Dollars	L	H	H	H
Education	M	H	L	?
Full Cost Pricing	M	M	H	L
Fuel Subsidy	H	H	M	H
Vehicle Subsidy	M	M	H	H

H - High
M - Medium
L - Low

This table lists a number of the more frequently mentioned policy options to reduce oil use and carbon from light vehicles.

I have estimated with a high, middle or low score the effectiveness, feasibility, cost and public acceptance for each policy.

CAFÉ or new fuel economy standards would be the most effective policy, and they have very high public acceptance.

Light truck gas guzzler taxes have not been tried, but could prove to be very effective.

Policy Preference

"If the nation determined that it is important to reduce greenhouse gas emissions from vehicles, which of the following policies would you prefer?"

- 17% prefer 25 cent per gallon tax on gasoline
- 70% prefer 3% tax for new vehicles

Source: Opinion Research Corp. for NREL phone survey 2/98

This survey result shows that respondents favor a tax on vehicles over a tax on fuels. Both taxes a intended to raise about the same amount of revenue.

Conclusions

- Demand for transportation will continue to grow at a strong pace
- Fossil fuels are abundant, but economic replacements for conventional oil will likely come from equally unstable sources and result in increased carbon emissions
- Solutions to the two transportation problems considered most serious are likely to increase energy use and carbon emissions
- Although conventional oil production may not peak for another 20-40 years, price shocks and associated economic losses will continue to be a threat

Conclusions

- Although the impact of global warming in unclear, environmental and economic damage from climate change could be significant
- If we are concerned about transportation's contribution to oil use and GHG emissions, then we must take action now
- To be effective, we need to better understand consumer/public preferences for advanced technologies and environmental policies
- Without consumer/public awareness, we can anticipate increasing demand for larger more powerful vehicles, furthering transportation's contribution to global warming

Future SUV's

The Peterbuilt Crusader

The International Himalaya
The first two-story SUV (elevator optional)

Source: http://poseur.4x4.org/futuresuv.html

Is this what the future will bring?

Future SUV's

The Peterbuilt Crusader
All Sport Denali
The worlds first king-size high performance sport brute

Source: http://poseur.4x4.org/futuresuv.html

The Kenworth Grand Dominator

- **Extra high roof/cathedral ceilings**
- **Power expandable sides**
- **Full lavatory**